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The Technique and Restoration of Cima's 'The Incredulity of S. Thomas'

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An account of the cleaning and transfer to a new painting support of *The Incredulity of S. Thomas* by Cima da Conegliano (No.816) (Plate 1, p.9) appeared in Volume 9 (1985) of the *National Gallery Technical Bulletin*, pp.38–59. The documented physical history of the painting up to its acquisition by the National Gallery in 1870 was also described since this may explain the considerable amount of damage the work has suffered and the fragile condition which made transfer necessary.

While the extent of the damage has led to a lengthy and sometimes problematic restoration which will be described in the last section of this article, it has also given members of the Scientific Department an unprecedented opportunity for taking samples from the edges of these losses. This has made possible a detailed survey of the materials and techniques used by Cima to produce his altarpiece.

The study has involved the examination of some sixty samples by microscopical and analytical methods including

Figure 1

SEM micrograph of the top surface of a fragment of gesso from Cima's *The Incredulity of S. Thomas* showing a separate application of glue size to seal the ground. Gold-coated, 1120 ×.

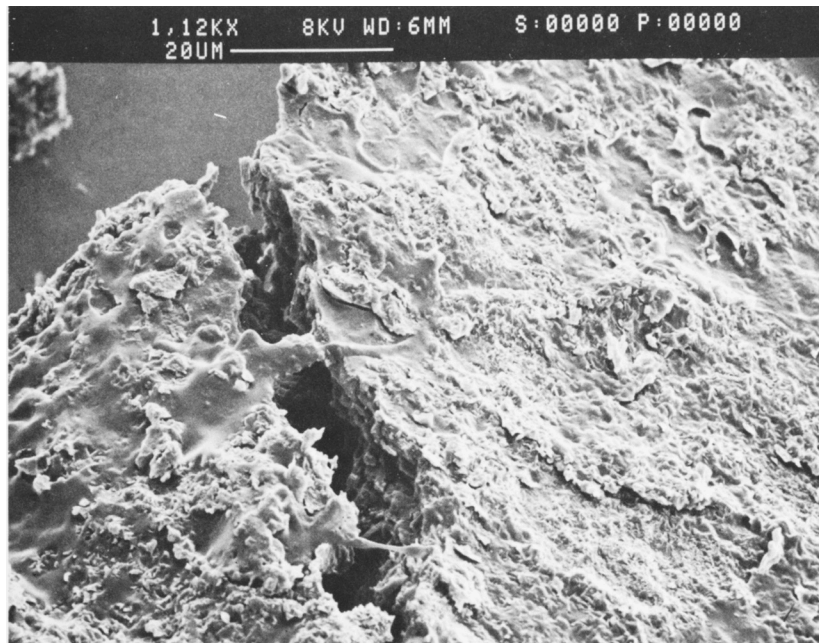


Figure 2

SEM micrograph of the interior of the gesso ground showing a granular texture which differs from the relatively smooth top surface seen in Fig. 1. Gold-coated, 3220 ×.



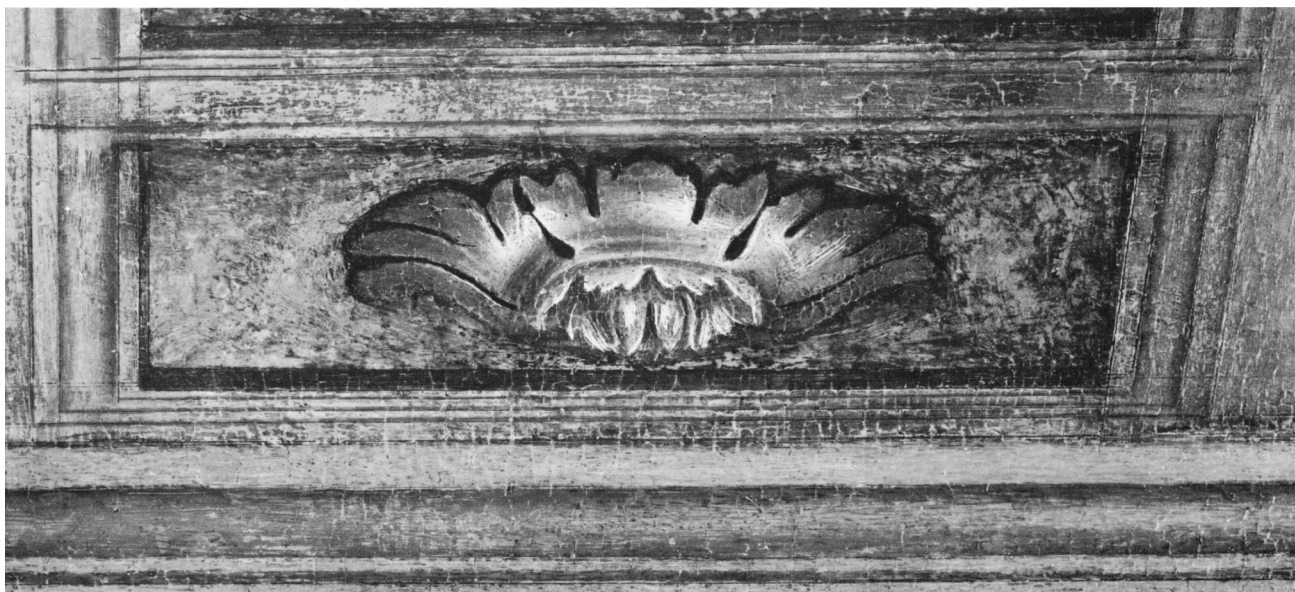


Figure 3
Detail after
cleaning and
restoration of
the coffered
ceiling.

spectrographic analysis with the laser microprobe (LMA), X-ray diffraction analysis (XRD), gas-chromatography (GC), mass-spectrometry (MS) and high-performance liquid chromatography (HPLC). Much of the information presented here has been derived from the examination of paint cross-sections in incident and transmitted light supported by ancillary analyses.

Support

The panel (which had to be removed entirely during the transfer) was approximately 5 cm. thick. It was made up from seven horizontal planks of poplar [1] using simple, glued butt-joints like those of most early Italian panels. The various battens, cleats and wooden blocks applied to reinforce the panel and joints were all later additions [2]. At some time before 1820 the top, which was probably originally rectangular, was cut down to the present irregular arch [3]. Repairs made by the panel maker to faults in the planks, such as knots, were discovered as the wood was planed down during the process of transfer [4].

Ground

The gesso ground (not removed during the transfer) is of a creamy white colour and consists of calcium sulphate in a binding medium of animal glue. X-ray diffraction powder analysis showed that the calcium sulphate is present in the dihydrate form ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) which occurs when the gypsum is used in its natural state from the mine and not burnt to drive off the water of crystallization (to produce the anhydrite form). The use of unburnt gypsum for gesso grounds seems to have been a standard practice in the Venice area, whereas in works from other regions, for example Florence and Siena, it appears that the grounds generally consist of anhydrite, either alone or mixed with the dihydrate [5].

As the last thin layer of wood was removed the surfaces of the chips and splinters which had been in contact with the gesso ground were examined for signs of any unusual preparation that might have been applied before the gesso, and therefore perhaps responsible for the failure of

adhesion of the ground to the panel. However, there was nothing to suggest that Cima (or whoever prepared his panel [6]) had used anything other than the usual animal-glue size as prescribed by Cennino Cennini [7]. If the painting's history of blistering and flaking was due to a technical fault (as opposed to neglect and poor environmental conditions) then possibly either too much or too little size was brushed onto the panel before application of the gesso.

In those cross-sections where a reasonable amount of gesso is present (for example, Plates 2a, 2g, 2k and 2j; p.12) the ground can be seen to be remarkably homogeneous in appearance. The divisions between the layers of gesso were only detected by a staining test [8]. In some of the sections a slight increase in the proportion of glue to gypsum is apparent towards the top of the gesso layer, but it is not easy to determine whether this is due to the separate application of size visible in Fig.1. A very definite separate size layer, presumably applied to reduce the porosity of the ground, can also be seen in samples from Cima's *Tobias and the Angel* in the Accademia, Venice [9], and some form of sealing layer has been noted on the gesso grounds of many Italian paintings of the second half of the fifteenth century [10]. As well as sealing the ground this layer may sometimes have been intended to reduce slightly the cold whiteness of the gesso. On worn and damaged areas of *The Incredulity of S. Thomas* the exposed ground has a warm, golden yellow colour. Although in this case the colour may be due to staining by old varnish and adhesives used in blister treatment, in thinly painted areas of other, less damaged works by Cima, a warm, often pinkish tinge to the ground can sometimes be seen [11].

Underdrawing

The architectural setting for *The Incredulity of S. Thomas* has been carefully constructed with an accurate use of single-point perspective, the orthogonals meeting at a point slightly to the left of Christ's exposed knee. The straight lines of the walls, the tiled floor and the ceiling beams have been incised into the gesso with a sharp point (Fig.3) and the curves for the tops of the arched windows



Figure 4
Detail of the back of the gesso ground during transfer, after removal of the wood of the panel.



Figure 5
Detail of the tiled floor and an Apostle's foot showing incised lines.

Figure 6
Detail showing
lines inscribed
into the paint
for the haloes.

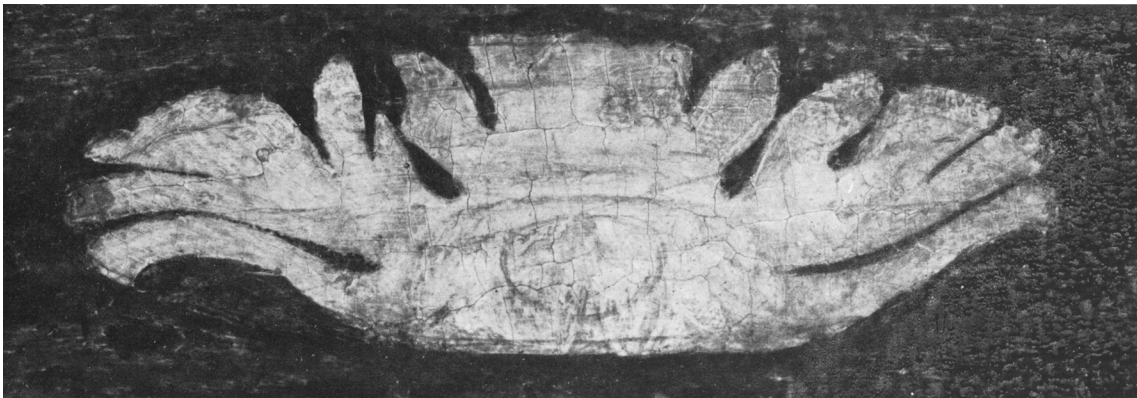


Figure 7 Infra-red detail after restoration of a ceiling rosette showing a rough sketching-in of the design. The retouchings show as slightly darker areas in this and the other infra-red photographs.

have been inscribed using a pair of compasses or dividers to draw the arcs [12]. These incised lines could be seen when the back of the gesso ground was exposed during the transfer (Fig.4). Although the perspective lines may have been drawn onto the gesso as the first step in designing the altarpiece, not all the lines can have been incised until the placement and drawing of the figures had been established [13], since the incisions for the tiled floor do not (apart from a few mistakes) run across their feet or draperies (Fig.5). At a later stage, the circles of the apostles' haloes have been incised, but only lightly so as to indent the paint layer rather than the gesso (Fig.6).

A thin layer of blackish underdrawing is visible in several of the cross-sections (for example, Plates 2g, 2k and 2j; p.12 [14], but the results of examination of the painting by infra-red photography and reflectography were not very revealing, with the underdrawing showing only in a few areas where it is also just discernible in ordinary light. These areas include the more thinly painted rosettes of the coffered ceiling (Fig.7), the pale pink skirt of the apostle third from the left (Fig.8), S. Peter's beard (Fig.9) and the right foot of S. Thomas, where a different design of sandal was originally intended (Fig.10).

The small amount of drawing that can be seen shows that Cima has used a style of underdrawing which is characteristic of many of his works: the ink or paint is applied in a fairly dilute state, using a smallish brush to produce a firm, even line. This technique is well illustrated, although on a much smaller scale, by infra-red photo-

graphs of *David and Jonathan* (No.2505) (Fig.11), where, as well as outlining the forms, Cima has used parallel, hatched brushstrokes to define the modelling of drapery folds and the distribution of the most important highlights and shadows. In the case of *The Incredulity of S. Thomas*, the presence of a layer of underdrawing in many samples taken from well within the boundaries of a form or colour area suggests the use of a similar method.

The reason why so much underdrawing can be seen in *David and Jonathan* and so little in *The Incredulity of S. Thomas* [15] may be connected with the relative thicknesses of their respective paint layers, those of the latter being too thick to allow the infra-red light to penetrate and then to be reflected back from the white ground; but it could also be related to the materials with which the drawing has been executed. It is generally assumed that when lines which have been applied with a brush show up under infra-red examination, they have been drawn using a simple ink consisting of some form of carbon black in an aqueous medium, possibly gum arabic. Few studies have been made of the composition of inks used for underdrawing, mainly because of the difficulty in obtaining samples and of separating the components of the drawing ink from the paint layers above and the ground below. However, it has been possible to obtain some reasonably uncontaminated samples of underdrawing from *The Incredulity of S. Thomas*. When the top surface of a sample from the outline of S. Peter's calf was examined under the microscope some sparsely distributed black particles could be seen, but the drawing appeared more as a dark, yellow-brown stain on the gesso. Spectrographic analysis of a second sample with the laser microprobe (LMA) showed the presence of iron in some quantity, so it would seem that the underdrawing may well have been executed with an iron gall ink. Iron gall inks sometimes occur in drawings on paper but they were more commonly used as writing inks. The ferric gallotannate, the insoluble salt that gives the ink its black colour, produces a reasonably dark image in an infra-red reflectogram but the image is less black and intense than that formed by a carbon black drawing ink, hence the relatively poor visibility in infra-red of the underdrawing on the altarpiece.

That Cima used iron gall inks in some of his underdrawings is confirmed by its identification as the drawing ink used on the unfinished *Virgin and Child with S. Andrew and S. Peter* in the National Gallery of Scotland [16]. Within the lines of drawing on *The Virgin and Child with S. Andrew and S. Peter* are also a few particles of carbon black [17]. These may represent traces of a preliminary drawing of the forms with charcoal or black chalk, which would then have been fixed and reinforced using the ink applied with a brush, exactly as recommended by Cennini [18]. The discovery of fairly large, splintered particles of charcoal underdrawing in a sample taken from the fingers of the apostle on the far left in *The Incredulity of S. Thomas* suggests that a similar sketching-in of the design took place. Any charcoal that had not been fixed by the subsequent brush drawing would have been dusted off before the application of the paint layers.



Figure 8 Infra-red detail of the pale pink skirt of the Apostle third from the left.



Figure 9 Infra-red detail of S. Peter's beard.

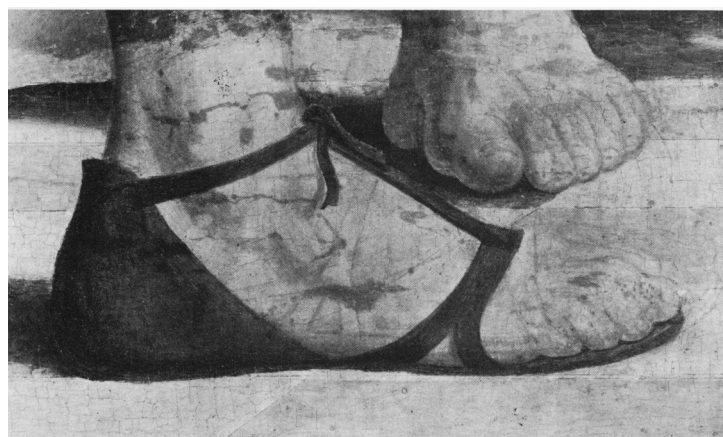


Figure 10 Infra-red detail of S. Thomas's foot showing that it was originally slightly longer and had a different design of sandal.

Plate 1

Cima, *The Incredulity of S. Thomas*
(No.816), after cleaning and
restoration.



The paint medium

Analyses by gas-chromatography were made on samples of paint from an ivory-coloured floor tile, a brown ceiling beam, the red robe of S. Thomas and the green robe of Apostle I. (See Fig.12; each Apostle, except S. Thomas and S. Peter, has been assigned an alphabetical letter for identification when describing the paint layers.) The basic medium of all four samples was found to be linseed oil [19]. In addition, samples of the orange-brown glaze over the yellow robe of Apostle C and of the green glazes on S. Thomas's robe and the mantle worn by Apostle I were investigated by mass-spectrometry. These contain some conifer resin, probably pine, mixed with the linseed oil [20].

There are no indications that any egg tempera has been used on the altarpiece, although egg has been identified as the principal medium of some areas of *The Virgin and Child with a Goldfinch* (No.634) [21]. It seems that, in common with many Italian painters working during the period of transition from egg to drying-oil-based media, Cima worked with both, perhaps reserving the use of tempera for smaller scale works.

Pigments and layer structure

Blue

There are several areas of blue paint on the altarpiece. These vary widely in colour, from the rich turquoise blue of the ceiling to the cold, pale blue or mauve drapery worn by Apostle D (probably identifiable as S. John).

Samples taken from the areas of blue-green paint between the beams and rosettes of the ceiling show that it has been applied in two layers (Plate 2a, p.12). The lower layer consists of a mixture of natural azurite and lead white.

The upper layer also contains azurite, but with less lead white and a higher proportion of medium. The medium has probably discoloured to some extent so the ceiling is now almost certainly rather darker and duller than when it was first painted. In addition, the upper paint layer has worn thin in several places and it is likely that the contrast between the lighter side on the left, and that in shadow on the right, was originally more marked. The unusually green colour of the azurite may be partly due to the effect of the discoloured medium, but the pigment, particularly in the upper layer, also contains a considerable amount of brown cuprite as an impurity in the mineral which would make the azurite appear less blue than usual. This suggests that the pigment was chosen deliberately for its greenish hue.

Azurite of a more usual colour also occurs in most of the other blue areas on the painting but only as an underpaint for the more expensive blue pigment, natural ultramarine (lapis lazuli) [22].

In the paint of the sky both pigments have been mixed with a high proportion of lead white. Although abrasion to the upper ultramarine layer has exposed some of the azurite underpaint, the ultramarine layer was clearly not continuous and the greener underlayer has been allowed to contribute to the colouring and modelling of the clouds.

The brightest and best preserved areas of blue paint occur on the robe of S. Peter, where the azurite and lead white underpaint has been glazed with a thin layer of good quality ultramarine mixed with a little lead white in the highlights and mid-tones. In the deepest shadows the ultramarine has been used with little or no lead white and the paint has probably darkened somewhat [23]. Again rather more of the azurite underlayer shows than when the altarpiece was first painted because of damage to the upper ultramarine layer.

Figure 11
Infra-red detail from
Cima's *David and*
Jonathan (No.2505),
40.6 × 39.4 cm.,
after cleaning,
before restoration.





Figure 12 *The Incredulity of S. Thomas*, after cleaning and restoration. Capital letters are used to identify the Apostles except for S. Thomas and S. Peter. The locations of the paint samples illustrated on p.12 are marked a–p.

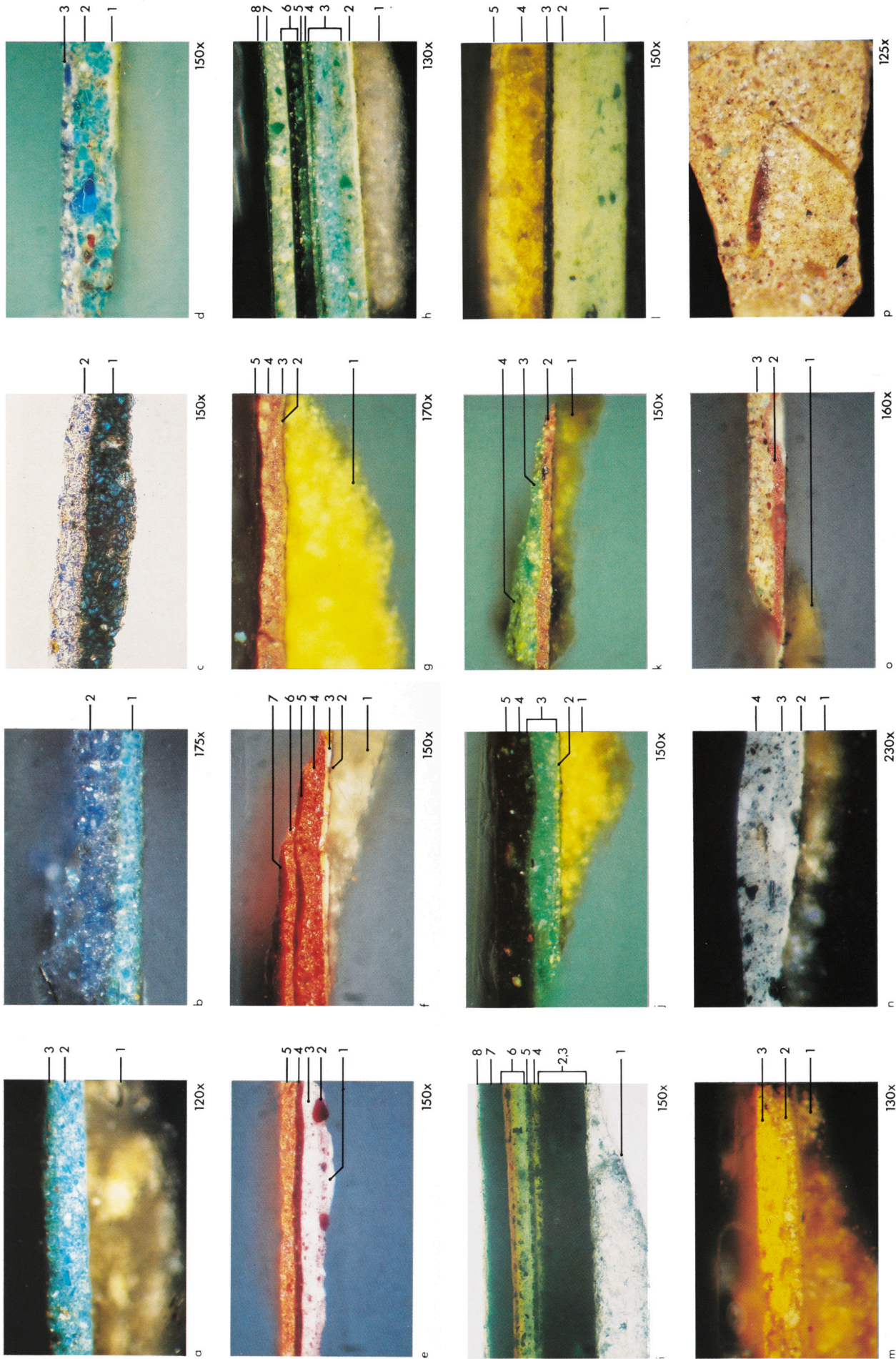


Plate 2 Cima, *The Incredulity of S. Thomas* (No.816). Full caption on facing page.

Plate 2 Cima, *The Incredulity of S. Thomas* (No. 816). Photomicrographs of paint cross-sections (*a–v*) and the top surface of a sample (*p*), photographed in reflected light at $220 \times$ (*a, b, d–h, j–m, o*) and $320 \times$ (*n*). Samples (*c*) and (*i*) are thin cross-sections, photographed in transmitted light at $220 \times$ under the microscope. Actual magnifications on the printed page are shown opposite. Sample locations are given in Fig. 12, p. 11.

- (a)** Blue-green paint of the ceiling.
 1. Gesso (gypsum) ground.
 2. Underpaint of azurite + lead white.
 3. Scumble of azurite with a little lead white. The azurite contains a fairly high proportion of the reddish brown mineral, cuprite, as an impurity.
- (b)** Blue mantle of Apostle A.
 (Gesso ground missing from sample.)
 1. Underpaint of azurite and lead white.
 2. Glaze of natural ultramarine.
- (c)** As sample (*b*), thin cross-section in transmitted light.
 1. As layer 1 in (*b*).
 2. As layer 2 in (*b*); note the relatively high proportion of colourless mineral impurities in the layer, and some discoloration of the oil medium.
- (d)** Mauvish blue drapery of Apostle D.
 (Gesso ground missing from sample.)
 1. Thin lead white underpaint.
 2. Underpaint comprising azurite, lead white and a little red lake pigment.
 3. Lilac surface paint containing natural ultramarine, red lake pigment and lead white.
- (e)** Opaque red highlight on the skirt of Apostle I.
 (Gesso ground missing from sample.)
 1. Thin lead white underpaint.
 2. Lead white mixed with red lake.
 3. Lead white + red lake + a little vermilion.
 4. Red lake glaze (elsewhere this layer forms the surface paint).
 5. Vermilion highlight.
- (f)** Shadow on S. Thomas's red robe.
 1. Gesso ground.
 2. Underdrawing.
 3. Thin lead white underpaint.
 4. Mixture of vermilion, red lake pigment and a little white.
 5. Layer of pure red lake pigment.
 6. As layer 4 above.
 7. Final glaze of red lake pigment.
- (g)** Mid-tone of purple-red robe of Apostle A.
 1. Gesso ground.
 2. Underdrawing.
 3. Thin lead white underpaint.
 4. Undermodelling layer for the drapery comprising haematite (crystalline red iron oxide) and lead white.
 5. Final glaze of red lake pigment.
- (h)** Mid-tone green of S. Thomas's drapery.
 1. Gesso ground.
 2. Thin lead white underlayer.
 3. Initial modelling layers containing verdigris, malachite and lead white. A single particle of natural ultramarine can be seen in the upper part of the sequence.
 4. 'Copper resinat' type semi-glaze containing a little suspended lead white.
 5. As layer 4 above, but containing rather more lead white.
 6. Series of glazes of 'copper resinat' with a red lake glaze as the final layer (see sample (*i*) below).
 7. Opaque green comprising malachite and/or verdigris combined with lead-tin yellow and lead white.
 8. Final 'copper resinat' green glaze.
- (i)** As sample (*h*) above, thin cross-section in transmitted light.
 The layers are labelled as in sample (*h*). Layers 2, 3 and 7 are completely opaque in transmitted light even as a thin section due to the content of lead white and lead-tin yellow in the paint mixtures. The glaze layers 4, 5, 6 and 8 are transparent or semi-transparent according to whether or not there is suspended opaque pigment (lead white) incorporated into the glaze. Note the presence of a glaze layer containing red lake pigment in the upper part of the series of layers labelled 6, the presence of which is not detectable in the reflected light photomicrograph (*h*).
- (j)** Deep green drapery of Apostle F.
 1. Gesso ground.
 2. Underdrawing.
 3. Three layers of opaque green undermodelling containing lead white mixed with verdigris and/or malachite. The lowermost layer of the sequence contains lead-tin yellow in addition.
 4. Layer of 'copper resinat' green.
 5. Surface glaze of red lake pigment.
- (k)** Dark green skirt of Apostle E.
 1. Gesso ground with underdrawing on top.
 2. Red underlayer comprising haematite, lead white and a little vermilion.
 3. Series of opaque green undermodelling layers, similar in composition to the series labelled 3 in sample (*j*).
 4. 'Copper resinat' glaze or semi-glaze. In another sample adjustments to the final colour have been made with red lake pigment.
- (l)** Yellow embroidered hem of S. Thomas's robe.
 (Gesso ground missing from sample.)
 1. Opaque green comprising malachite + lead-tin yellow + lead white.
 2. Light yellow-green: mainly lead-tin yellow mixed with white containing just a little green pigment.
 3. 'Copper resinat' glaze.
 4. Dark yellow of embroidery comprising lead-tin yellow, yellow earth pigment and a transparent yellow, possibly a lake.
 5. Highlight of lead-tin yellow ('type I').
- (m)** Bright orange-yellow highlight on S. Peter's mantle.
 1. Gesso ground.
 2. Khaki-coloured underpaint consisting of lead white mixed with a transparent brownish yellow, probably a lake pigment, and a little black.
 3. Orange-yellow highlight: mainly orpiment with a little realgar.
- (n)** Mid-grey shadow on Christ's drapery.
 1. Gesso ground.
 2. Thin lead white underpaint.
 3. Cool grey underlayer made up of a vegetable black pigment mixed with lead white.
 4. Warm grey surface paint comprising bone black + white.
- (o)** Shadow of Christ's flesh in the crook of the elbow.
 1. Gesso ground with underdrawing on top. The thin lead white underpaint present in other samples can be seen as a discontinuous layer in this cross-section over underdrawing.
 2. Underpaint of haematite, vermilion and lead white.
 3. Paint of the flesh comprising lead white, vermilion, black and a transparent orange-brown pigment. A little red lake is also present, and a few particles of natural malachite have been added to lend a cold tone to the paint.
- (p)** As sample (*o*), top surface of the paint sample.
 The pigment mixture is described in layer 3 for sample (*o*). One or two particles of natural malachite are visible. A coarse and a fine brush hair can be seen embedded in the paint surface.

The dull colour and lack of definition in the drapery folds of the blue mantle worn by Apostle A can probably be attributed both to the wearing of the upper paint layer and to the discoloration of the large quantity of medium mixed with the ultramarine in this layer (Plates 2b and 2c, p.12). However, the cross-section also shows that the pigment is not of particularly high quality, containing a large proportion of mineral impurities. Therefore the blue of this drapery can never have been as bright as that of S. Peter and was obviously not intended to be so, since it appears on a less important figure who is supposed to be standing further back in the imaginary space of the composition.

Cross-sections made from samples of the cool mauve-blue drapery worn by Apostle D show three separate paint layers (Plate 2d, p.12). At the bottom, directly over the gesso or underdrawing (if present), is a thin layer of lead white unmixed with any other pigment. This layer, which occurs under certain colour areas elsewhere on the altarpiece and on several other paintings by Cima [24] and his contemporaries [25], may have been intended to give greater brilliance and reflective power to the ground, adding to the richness of the colours. Perhaps it was also used to help mask areas of underdrawing that might otherwise have remained visible through the subsequent paint layers. Over this white priming is an underpaint of azurite mixed with lead white, and a red lake pigment to give the colour a more purple tint. This has then been glazed with ultramarine, again combined with red lake and lead white. The amount of lead white in the mixture varies according to the modelling of the folds. Neither the azurite nor the ultramarine are of especially good quality and the shadows in particular have a slightly greyish cast which suggests that some deterioration may have taken place. In other areas the azurite and red lake underlayer has only been covered thinly, if at all. This produces the effect of a slight satin-like sheen on the fabric. A mixture of ultramarine, red lake and lead white has also been used for the wedge of drapery below the grey beard of Apostle H, but the azurite underlayer has been omitted for this small area of colour.

Red

The red and pink draperies also cover a wide colour range, but the cross-sections show that they have all been painted using various permutations of a basic palette of three red pigments together with lead white.

The simplest technique occurs in the pale pink skirt of Apostle C and in the dark, ruby red mantle of Apostle F. Both have been painted with a red lake pigment combined with varying amounts of lead white. In the case of the former, a high proportion of white has been added (except in the deepest shadows) [26] and the paint has been applied over the same lead white priming noted in the samples from the pale blue robe worn by Apostle D. In the drapery of Apostle F the red lake appears to have been mixed with only a little lead white, and probably some vermilion in the lightest areas, and painted directly over the gesso ground.

Red lake and lead white are also the principal pigments in the robe of Apostle I. A cross-section made from a sample taken from an area of deep shadow (near the figure's waist) shows a fairly complex layer structure: over the lead white priming is a thin layer of red lake which

may represent a preliminary blocking-in of the shadow. This is followed by an opaque layer of red lake mixed with white and a very little vermilion, and then finally at least three layers of red lake glaze [27]. The dyestuff of the red lake glazes elsewhere on the painting has been identified probably as lac [28]; it has been precipitated onto a substrate of alumina [29]. The lighter parts of the sleeve have been painted with a simpler technique consisting of an underpaint of red lake and white glazed with a thin layer of red lake. In areas where this glaze is very thin it tends to have a slight brownish tinge so some fading and discoloration may have taken place. The appearance of a cross-section from the same figure's skirt (Plate 2e, p.12) is complicated by a layer of vermilion over the top of the expected layer structure of opaque pink underpaint and red lake glaze. There is nothing to indicate that the vermilion layer is not original, so it would seem that Cima made late alterations to parts of this drapery, either because the colour had become too dark through the application of too thick a glaze or perhaps because it proved to be colder than expected. Traces of adjustments made with vermilion can also be seen on the lighter parts of the surviving paint around the neckline of the same garment. Shrinkage cracks have tended to form in these re-worked areas probably because the relatively lean and quick-drying vermilion paint has been applied over the completed red lake glazes which are rich in medium and by their nature dry at a slower rate.

The bright red robe of S. Thomas has been painted primarily with vermilion and then glazed with red lake in the shadows. However, the cross-sections do not show the straightforward layer structure that might have been predicted. Both samples (from a shadow, Plate 2f, p.12, and from a relatively light area, not illustrated) contain two opaque layers of vermilion mixed with a little red lake and lead white according to the modelling of the folds. These alternate with layers of transparent red lake glaze to produce a structure of five distinct layers (including the lead white priming). It is possible that the whole or parts of this drapery had to be repainted for some reason [30] but areas of red paint with multiple alternating layers of opaque and transparent pigments have been noted on other Venetian paintings [31]. Perhaps there was some traditional theoretical basis for this practice. If so, it was presumably intended to produce a colour of the greatest possible richness and intensity.

The sample from the dull, purple-red robe of Apostle A (Plate 2g, p.12) is of considerable interest as it shows that, beneath the glazes of red lake, there is an undermodelling with a colour based on haematite, a crystalline form of red iron oxide which is seldom identified as a pigment in oil painting [32]. Haematite has also been used in the dark red skirt of Apostle E. In the cross-section two opaque layers can be seen over the lead white priming: the first consists of haematite and lead white with a small amount of vermilion and red lake, while the second, upper layer includes a higher proportion of vermilion and red lake, making a rather brighter colour, so that, with the final glaze, the drapery appears quite different in hue from that painted with haematite as the sole red pigment in the underlayer.

Figure 13
Detail of the
neckline of S.
Thomas's
robe.



Green

Areas of green on paintings by Cima are generally remarkable for their brilliance of colour and good state of preservation. Those on *The Incredulity of S. Thomas* are no exception.

The only sample of paint from the grass and foliage was taken from the pale green slope in the left-hand landscape. It was found to contain natural malachite mixed with lead-tin yellow and lead white and applied in a single layer over the lead white priming noted elsewhere on the altarpiece.

This lead white layer also occurs in some, but not all, of the six cross-sections made from samples of the bright green draperies worn by S. Thomas and Apostle I. The layer is usually very thin and was probably brushed on quite freely so some areas of the gesso may have been missed and left uncovered. Over the priming lie up to as many as ten separate layers of paint; the cross-sections from these greens are by far the most complicated of all those taken from the painting (Plate 2h, p.12). The first two or three layers consist of opaque greens made up from varying combinations of malachite and verdigris with lead white and sometimes lead-tin yellow in addition. In a darker sample from Apostle I the three opaque layers have been divided by a dark green semi-transparent layer which probably represents the blocking-in of a shadow like that noted in the same figure's pink robe.

As might be expected, these opaque underlayers have been glazed with 'copper resinate' or with a semi-transparent layer of verdigris or 'copper resinate' containing a little white [33]. In the very complex dark sample from Apostle I, the true glazes are preceded by a 'semi-glaze' as well. In all the samples, apart from that taken from a light area of the decorated hem of S. Thomas's skirt, these apparently completed glazes have been covered with

another opaque layer of malachite and/or verdigris mixed with lead white and rather more lead-tin yellow than is generally seen in the lower opaque layers. Finally, more glazes of 'copper resinate' have been applied, their thickness depending on the modelling and lighting of the drapery folds.

There is no suggestion that the upper opaque and transparent layers are later additions, and an extraordinary number of layers is sometimes a feature of the greens in Venetian paintings [34]. What is unusual about the greens on Cima's altarpiece is that in each sample, at the top of the first application of green glaze, there is a thin brown-coloured layer which might easily be taken for discoloured 'copper resinate'. This would suggest that the glazes had discoloured for some reason while the work was still being painted, thus explaining the need to repaint the draperies. However, when some of the samples were prepared as thin-sections for examination in transmitted light under the microscope [35] (Plate 2i, p.12) it became apparent that these layers were not browned 'copper resinate', but a distinct intermediate glaze containing red lake. When, in a cross-section, a colour occurs which seems to bear no relation to the colour of the paint from which the sample comes, it is usually attributed to a pentiment or to the overlap of different coloured forms; but, in this case, the red lake is found in samples taken from well within the boundaries of three quite separate areas of green paint. Putting aside such improbable explanations as Cima having had a colour-blind workshop assistant, to account for the presence of this red glaze it is necessary to turn to one of the other green areas in the painting, the rich, deep green worn by Apostle F (Plate 2j, p.12). Here the opaque green underlayers and green glazes have been completed with a fairly thick layer of red lake, the function of which is clearly to darken the drapery so as to make the figure



Figure 14
Detail of the embroidered pattern on the hem of S. Thomas's robe.

recede into the composition, but without making the colour turbid and opaque as would have been the result if a pigment that does not form a fully transparent glaze had been used, for example ultramarine or black.

It follows that the red glazes in the lighter green draperies were perhaps associated with a similar attempt to deepen and intensify the colour and the contrast between highlights and shadows in the modelling of the folds. They must also have been intended to modify the hue of the green paint beneath. Judging by the pigment mixtures in the uppermost layers of the lowest series of opaque underlayers, with their high proportion of malachite and verdigris (and in one instance even a few particles of ultramarine) and little or no lead-tin yellow, the colour of the draperies would probably have turned out to be undesirably cold and blue when glazed with 'copper resinate', itself a rather cold colour when freshly prepared. In addition, before the painting was restored small areas of this first underpainting could be seen, particularly on S. Thomas's sleeve, where the upper paint layers together with the intermediate green and red glazes had flaked off. The colour revealed can be more accurately described as pale turquoise rather than light green. The colour of the second underpaint (visible in many areas where the final glazes have worn thin) is much warmer and brighter, especially in the highlights. This is due to the addition of a higher

proportion of lead-tin yellow than in the earlier opaque layers.

The first, red-glazed versions of the draperies must have been virtually finished before the decision to repaint them was made, since the slightly raised yellow paint of an apparently complete embroidered pattern around the neckline of S. Thomas's garment can just be seen through the superimposed paint layers (Fig.13). The surviving sections of the decorated hem on the skirt do not appear to have been repainted. Over the green background to the embroidery is a damaged and now rather brown-coloured glaze which makes the green much darker than that of the undecorated area immediately above it (Fig.14). This glaze is probably all that remains visible of Cima's unexpected experiment with different coloured glazes.

The only other green drapery, that of Apostle E, may contain a thin layer of red lake but it also includes a layer of red as part of the underpaint (Plate 2k, p.12). On this occasion, however, it probably does represent an alteration to the design, since the pigment mixture of haematite with a little vermilion and lead white is identical to that of the lowest layer of the same figure's red skirt. The change to the outline of the green robe must have been made after the first red layer was blocked-in and before the modifications to the red colour described earlier.

Yellow, orange and brown

The largest area of yellow paint is that of the robe of Apostle C. The main pigment used for the undermodelling is lead-tin yellow [36], but in a sample from a darker area there is also a little vermilion and possibly some form of orange or yellow organic pigment. The amount present is too small for identification but it may account for the robe having a rather warmer, more golden colour than that usually associated with lead-tin yellow alone. The shadows and the modelling of the folds have been intensified by the application of a glaze consisting of a transparent orange pigment in an oleo-resinous medium of linseed oil and conifer resin. The orange-brown colouring material has been identified as a softwood tar (see p.66 of this *Bulletin*). Softwood tars are formed by wood resins during the slow burning of the wood as in, for example, the manufacture of charcoal. Transparent brown glazes have frequently been noted on sixteenth-century Venetian paintings [37] but this is the first positive identification of the actual colouring material on a work from that School in the National Gallery. It also appears to be the first time that a softwood tar has been identified in use as a pigment to colour glazes, although it is known to have been used as an adhesive since ancient times. It would almost certainly have been obtainable from the same apothecaries where the painters procured their pigments and other materials. It seems to have made a rather satisfactory pigment, exhibiting none of the drying defects associated with bituminous transparent browns and it has resisted abrasion and damage from past cleaning and blister treatment as well as any of the other coloured glazes of comparable thickness.

The embroidered patterns around the hems and necklines of some of the robes and mantles (Fig.14 and Plate 2l, p.12) have been painted over the fully modelled drapery folds using a dark yellow colour which has the appearance of yellow ochre but, in fact, seems to be a mixture of lead-tin yellow with a little yellow ochre and a transparent yellow pigment, possibly a lake [38]. As the transparent yellow pigment occurs in a mixture and in relatively small quantities, it has not been possible to identify the type of the dyestuff [39]. The patterns have then been highlighted in imitation of gold threads with delicate touches of pure lead-tin yellow. The only real gold on the altarpiece is in the form of 'shell-gold' which has been used for the rays of Christ's cruciform halo and for the circular haloes of the Apostles (Fig.6). The appearance of a sample from the pale ivory yellow paint of the floor tiles suggests that it too may contain some yellow lake, together with very small amounts of lead-tin yellow, vermilion and black, all in a matrix of lead white.

The cross-sections from the orange mantle of S. Peter (Plate 2m, p.12) show the technique to have been fairly complex. Over a white priming (which as before does not seem to be a continuous layer since it is not present in all the samples) is a khaki-coloured underpaint containing lead white, a transparent brownish yellow (again probably a lake) and black. Before restoration, this undermodelling could be seen in several areas where it had been exposed by damage to the upper paint layers. The main paint layer is based on the yellow and orange sulphides of arsenic, orpiment and realgar, most likely of mineral origin [40]. In a sample from a highlight along the right edge of the robe

the khaki underpaint is covered by a single layer of yellow orpiment and orange realgar, with the orpiment predominating. In a slightly darker sample there is a higher proportion of realgar and also a thin orange-brown glaze, perhaps the same softwood tar identified on the yellow drapery. In the darkest sample (from the side of the figure in shadow) only realgar is present, and this has been mixed with more of the orange-brown glazing pigment, and a little red earth and umber [41] to make a rich semi-transparent brown.

The ceiling beams have been underpainted with a colour similar to that used for the underlayer of S. Peter's drapery. It too consists of lead white and a transparent yellow, together with small amounts of black and vermilion and possibly also some earth pigment as a minor constituent. Over this is a darker layer of the same pigment mixture, but with a higher proportion of black and vermilion. Finally, the mouldings have been defined with a glaze of black mixed with a transparent yellow-brown. A transparent orange or yellow pigment may also have been added to the upper paint layer of the pinkish brown floor tiles, since the lead white matrix which surrounds the particles of vermilion (the principal colouring component) has a definite warm yellow tint. The lower paint layer is a paler and much cooler pink, containing only lead white mixed with an unusually dark shade of vermilion.

Black and grey

The strongest black areas in the painting, on the sandals worn by some of the Apostles, are in fact, strictly speaking, dark brown, as the paint has been found to combine a certain amount of vermilion, red lake and lead white along with the black pigment. Two black pigments have been used: one consists of very fine, brownish particles and is possibly a bone black, while the other has larger, slightly shiny particles and is probably some form of vegetable black. However, it seems not to be a wood charcoal since the particles do not have the long, splintered shapes associated with charcoal.

The warm, slightly pink tone of the grey walls is not due to the addition of any red pigment, but rather to the use of the fine-grained brown-black, here identified as bone black [42] mixed with lead white. Some of the bluer, vegetable black has been added to this brown-black in the shadowed areas on the right.

The colour difference between the bone and vegetable blacks has been exploited with great subtlety in painting Christ's drapery (Plate 2n, p.12). The shadows and mid-tones appear to have been underpainted with a cool, blue-grey based on the vegetable black pigment. Over this has been applied a warmer and generally slightly darker grey made from bone black, but in some areas the cooler underlayer has been left uncovered so that the fabric seems to have a cold, metallic gleam. A similar colour variation has been obtained in the highlights by sometimes applying lead white [43] mixed with a very small amount of bone black directly over the gesso ground to make a warm, yellowish white; and sometimes dragging the lead white over the darker greys beneath. This produces the optical effect of a silvery, blue-white.

Flesh and hair

Each of the twelve figures is very individually characterized and their complexions range from the deep, ruddy tan of S. Thomas to the cold pallor of Christ. The flesh paint of three other figures, as well as these two extremes, was examined and the samples show that to achieve this variation Cima has used several pigments in a number of different permutations.

Samples from S. Thomas's neck and foot both contain a mixture of lead white, vermilion, the brown bone black and probably some orange or yellow transparent pigment. Over this is an orange-brown glaze identical in appearance to the softwood tar identified on the yellow drapery. The more sallow colour of the elderly Apostle A is based on a combination of lead white, red lake, vermilion, black and a transparent orange-brown. In this particular sample (from his fingers) the black is a vegetable black. Apostle C has a fairer, pinker complexion to go with his reddish hair and a sample from his foot was found to consist of a single layer of lead white, vermilion, red lake and a little black. The lightest areas of flesh paint on Apostle D are as pale as those on Christ but they tend to have a rosier, more healthy-looking aspect. This has been achieved using lead white with a little vermilion, black and transparent brown.

The reason for the slight difference in colour between the flesh of this figure and that of Christ can be found in a sample taken from a highlight on the latter's torso. Mixed with the lead white is some vermilion and red lake, but also present is a certain amount of the pale green mineral pigment, malachite. In a darker sample from a shadow in the crook of Christ's elbow (Plates 2o and 2p, p.12) the mixture of lead white, vermilion and malachite, together with some black and transparent orange-brown, has been applied over a much darker underpaint of haematite, vermilion and lead white. The resultant optical effect gives the flesh a cold, death-like greyness entirely befitting the subject.

To cover the range of different hair colours, samples were taken from the dark hair of S. Thomas, the red-brown hair of Christ and the grey beard of S. Peter. The paint mixture from S. Thomas's hair is rather like that used for the sandals. It includes both types of black pigment and lead white, but haematite has replaced vermilion and red lake as the red pigment [44]. Christ's hair has been painted over a lead white priming (also present under the flesh) with a combination of vermilion, a transparent yellow, lead white and a black pigment which here is probably a wood charcoal. Charcoal has also been used as the black pigment mixed with the lead white to make the grey of S. Peter's beard. On all the figures with grey hair and beards there appears to be a warm, honey-coloured underlayer beneath the thinly applied grey paint. In the sample from S. Peter the only pigments that could be seen apart from the lead white and charcoal, were vermilion, red lake and a very few particles of malachite. However, the sample was taken from a point where the beard is beginning to merge into the flesh paint beneath the cheekbone. Elsewhere the underlayer is quite yellow and must surely contain some transparent yellow pigment, probably in a similar pigment mixture to that used for Christ's hair but with a greater proportion of yellow and white.

Method of painting

If *The Incredulity of S. Thomas* had been a less extensively damaged painting and consequently it had been possible to take samples from only a few areas, for example, from the green drapery of Apostle I, the orange cloak of S. Peter and the flesh paint on the inside of Christ's elbow, the cross-sections would have been liable to misinterpretation and the technique used for the altarpiece would have appeared extremely complex and even bizarre. However, because the wide distribution of the damage has permitted sampling of most of the colour areas, it can be shown that in general the method of painting has a logic and consistency that is in keeping with the rest of Cima's artistic personality.

Cima's technique is founded on a detailed and thorough preliminary planning of the designs of his works. Pencil sketches in the sense of alterations to the drawing of the forms are rare and usually just involve slight adjustments to an outline or the fall of a piece of drapery [45]. The few visible changes of this type on *The Incredulity of S. Thomas* include the narrowing of the lower end of Apostle A's sleeve, small corrections to the hem-line of Apostle I, the decision not to paint S. Thomas's sandal according to the pattern in the underdrawing and the presumed alteration to Apostle E's red and green draperies as revealed by the cross-sections (see p.16).

Once the design had been fully established almost all the colour areas were blocked-in with a more or less opaque underlayer or sequence of underlayers. With the exception of parts of Christ's grey robe, this is always paler and less saturated than the final colour obtained when it has been completed by glazes. Generally it is neither so opaque nor so thickly applied as to block-out all the light which reflects back from the gesso ground or from the lead white priming where this is present; nor is it totally flat and unmodulated. In the draperies the shadows of the folds are defined using a slightly darker pigment mixture than that used for the highlights: for example on S. Thomas's red mantle, red lake has been added to the vermilion and lead white in the darker areas whereas elsewhere vermilion and lead white have been used alone. Cima seems to have run a large and busy workshop [46] and for an altarpiece of the scale of *The Incredulity of S. Thomas* some studio assistance might be expected in the application of these underlayers.

X-radiographs of paintings by Cima, including the only one from *The Incredulity of S. Thomas* (Fig.15), show that the undermodelling was sometimes blocked-in quite freely and boldly. Clearly defined brush marking is often visible which suggests that fairly large, stiff, hog's hair brushes may have been employed. By chance, embedded in the sample from the inside of Christ's elbow is what might be a bristle from a hog's hair brush (Plate 2p, p.12). Next to it are some finer hairs; these probably come from a smaller, softer brush made from squirrel hair or miniver tails [47] and used for executing the finer details in the upper paint layers.

The upper paint layers consist mainly of glazes of transparent and semi-transparent pigments. Even in the faces much of the detailed modelling has been accomplished using orange and brown semi-transparent colours (Fig.16). In the draperies the glazes can have been applied thickly and in several layers to achieve maximum depth and inten-

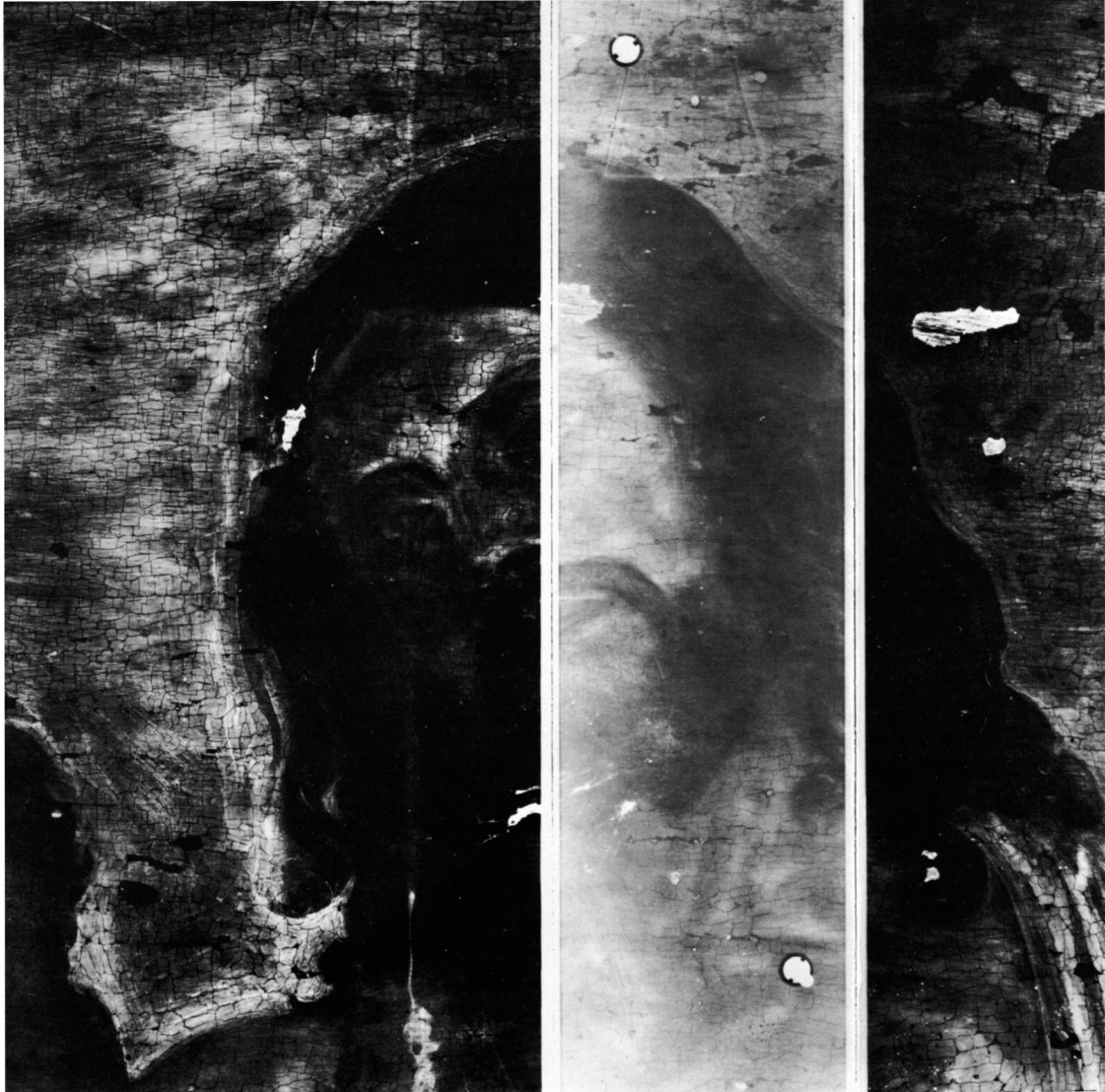


Figure 15 X-radiograph detail of Christ's head, before transfer. The light band is due to a metal strut applied to reinforce the original panel before the decision was made to transfer the painting.

sity in the shadows of the folds, or, in lighter areas, quite thinly so that they just slightly modify the colour of the opaque layer beneath (Fig.17). Fingerprints can sometimes be seen in the thin glazes where Cima has presumably sought to blot off surplus paint and soften the transitions in the modelling (Fig.18). The strong sculptural effect of Cima's drapery painting has been achieved largely by careful control of the thickness of the glaze layers.

Use of colour

By the standards of the fifteenth- and sixteenth-centuries, Cima seems to have used an exceptionally wide palette of pigments in many different combinations to achieve such an extensive colour range that virtually the only colour to be repeated is the light green worn by S. Thomas and by Apostle I. However, it is possible that if other paintings of a similar size and complexity of design were examined and analysed in as much detail as Cima's altarpiece, then an

equally full selection of pigments might be found. As Venice was the centre of the European pigment trade [48] Cima was well-placed to procure a good range of colours. Among the mineral pigments, not only could he obtain less common colours like haematite, orpiment and realgar, but he could also find alternative shades derived from the same basic mineral source, for example the deliberate use for the blues of azurite and ultramarine of varying qualities and purity. The range of organic red, yellow and brown glazing pigments is also remarkable. The only pigments which are notably absent (except occasionally as minor constituents of mixtures) are the yellow and brown earths. In all the areas of brown paint investigated, they have been replaced by mixtures of lead white, black, various reds and a transparent yellow. Even the browns of the landscape which were not sampled, are likely to have been executed with variants of this pigment combination.

The way in which the areas of colour are distributed adds to the three-dimensional illusion of the altarpiece and intensifies its narrative content. The figure of Christ is clearly emphasized by its height and by its central position in the composition but it is also singled out by the relative absence of colour. At the other extreme are the figures of S. Thomas and S. Peter who stand furthest forward in

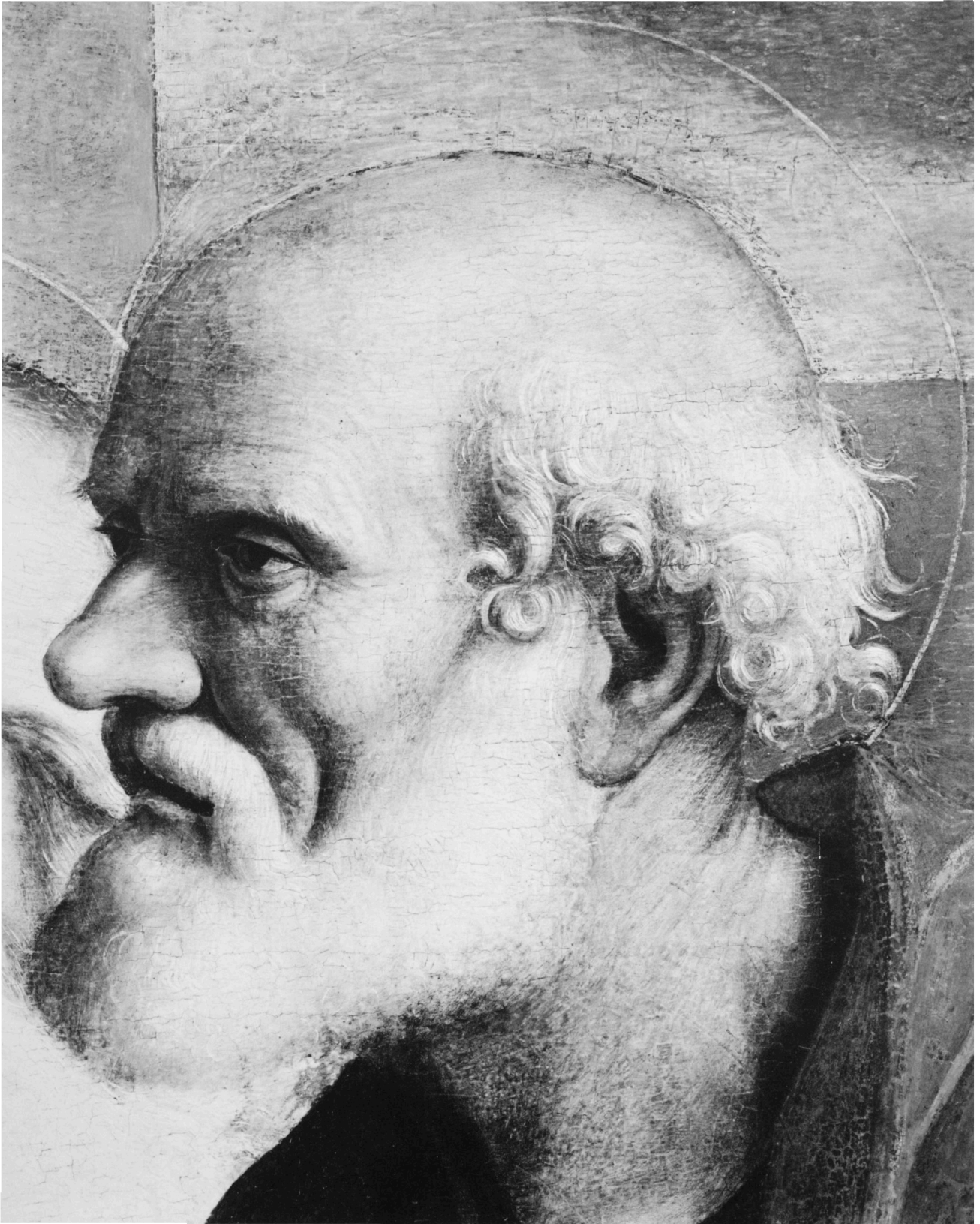


Figure 16 Detail of the head of S. Peter.



Figure 17
Detail of the
sleeve of
Apostle I.

their respective groups and some way in front of Christ, and have been dressed in the brightest possible shades of red and green, and orange and blue. It may just have been a fortunate coincidence that the colours worn traditionally by these two Apostles in Italian paintings happen to be exactly complementary and opposite to one another in the colour circle. Colour circles and the theory of complementary colours were only developed in the eighteenth century, but the concept of contrasting colours and their mutual enhancement appears to be Aristotelian in origin and is discussed in the treatises of Alberti and Filarete (who particularly praised the combination of red and green) [49]. Therefore it is not impossible that Cima was consciously aware of the vibrant effect of certain colours upon one another and exploited it in his placing of these two figures. The need for the green robe of S. Thomas to complement the red of his mantle may have been another reason for abandoning the experiment with red glazes disclosed by the cross-sections. The effect of this use of complementary colours can be assessed by comparing the draperies of S. Thomas with those of Apostle I on the far left of the composition. Although the latter is wearing an identical shade of green it appears less intense because it has been set

against a red which is too cold and blue for maximum colour contrast. The use of the same green for this figure may have been intended as a device to direct the eye of the viewer who reads the painting from left to right, back to the green of S. Thomas's sleeve and the act which is the focus of the composition. The crucial gestures of Christ and S. Thomas are also stressed by being placed in front of the pastel-coloured draperies and pale flesh of Apostles C and D. It has been demonstrated in the account of the pigments and layer structure that the colours of the remaining Apostles have been chosen and, if necessary, adjusted, so that they will recede and take their places at the rear of the figure groups on either side of Christ. In the case of Apostle F this has involved not only the deepening of the colour of his green robe by the application of a red lake glaze but also an alteration to the colour of his hair. Damage to the upper paint layers showed that originally this was painted as grey and only later changed to a dark brown.

Restoration

In deciding upon an approach to the restoration of the many paint losses which have occurred as a result of the altarpiece's long history of flaking, it was thought important to respect the great care that has been taken to construct a convincing illusion of three dimensions on the flat picture surface. *The Incredulity of S. Thomas* is a typical Venetian *pala* of its period representing an attempt to create an imaginary space in which the figures depicted appear to exist beyond the walls of the church or chapel where the work is to be hung. In this case, the illusion has been heightened by the precise and consistent lighting of the



Figure 18 Detail showing fingerprints in the glaze layer of the green robe worn by Apostle I.

figures and their setting, by a clever use of colour, and by the sculptural modelling of the figures themselves [50].

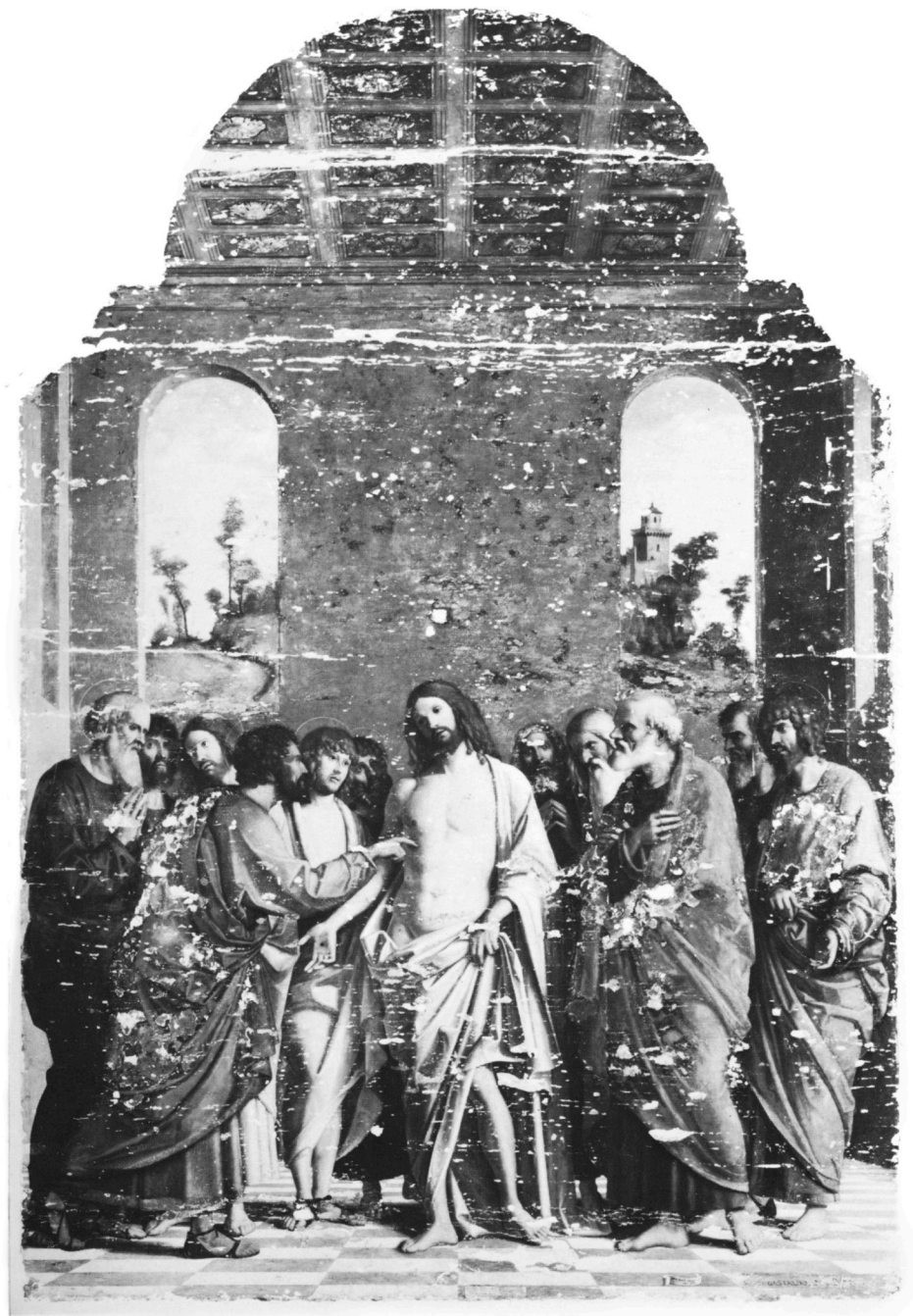
It can be seen in the photographs of the painting taken after cleaning and before restoration (Fig.19), that the three-dimensional illusion is broken up and virtually destroyed by the areas of paint loss. These appear to float in front of the picture space, interfering with the legibility of the design. This disruption to the image would only have been slightly reduced if the losses were retouched using one of the clearly visible systems of restoration devised for extensively damaged paintings: for example, the use of so-called neutral colours, or the more obvious forms of *tratteggio* such as 'abstract chromaticism' [51]. A subtler use of hatched brushstrokes or a 'pointillist' application of the retouching can be effective on certain paintings, but it was concluded that the restored areas would appear oddly soft and unfocused on such a strongly lit and crisply modelled

work as Cima's altarpiece. Another difficulty which occurs when using a visible as opposed to an imitative technique of retouching is in the logical application of the system, especially on a work like *The Incredulity of S. Thomas* where the losses to be restored vary in size from the needle holes made in the past when injecting adhesives for blister treatment to the large loss comprising most of the chest of Apostle I.

For these reasons most of the damage on the altarpiece has been retouched to match the condition of the better preserved areas of paint. Fortunately the heads have escaped serious damage, the worst affected being that of Apostle F. The hands and feet are in good condition, the only exception being the feet of Apostle D. All the large losses are located in less important parts of the composition.

The nineteenth-century restoration removed before the painting was transferred, was of no assistance in the present

Figure 19
The picture after
cleaning and transfer
before restoration.



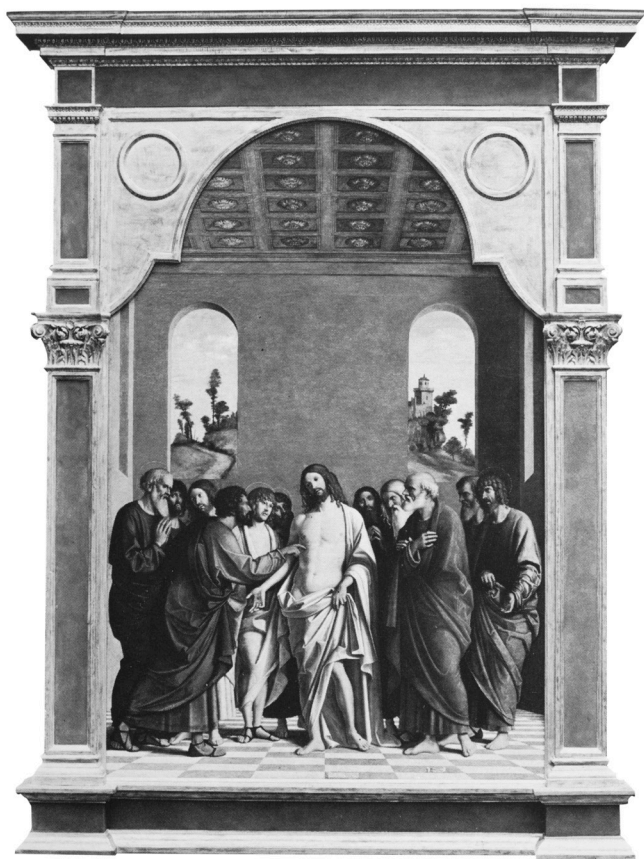


Figure 20 (top) The altarpiece before cleaning, in its nineteenth-century frame.

Figure 21 The altarpiece after cleaning and restoration as it is now exhibited.

restoration, as the damaged draperies, including those of S. Thomas, S. Peter and Apostle I, had simply been repainted, often ignoring and covering large areas of relatively well-preserved original paint. *The Incredulity of S. Thomas with Donors*, an altarpiece by an unknown artist in the Church of S. Niccolò in Treviso, which is the only known work to have been influenced by Cima's composition, provided some guidance in rebuilding the folds of S. Peter's orange mantle. The other figures bear little resemblance to those of Cima, except the S. Thomas who, unfortunately, is based not on his counterpart in the National Gallery altarpiece, but on the quite different figure in Cima's apparently later version of the subject in the Accademia, Venice.

Although other paintings by Cima were also consulted most of the evidence used for the restoration of *The Incredulity of S. Thomas* was deduced from the altarpiece itself. Frequently, when reconstructing the larger areas of missing paint, fragments of original paint were found to have survived to supply significant clues as to what might once have been painted. This was particularly the case with the feet of Apostle D; once the confusing remains of an earlier reconstruction (pre-dating the nineteenth-century attempt) had been eliminated, the original pattern of the sandals became apparent. Elsewhere, in the large loss of Christ's grey robe where it folds over the bend in his arm, for example, logical solutions were found by imitating Cima's precise draughtsmanship and by following the consistent lighting scheme used throughout the painting.

In restoring certain areas compromises have had to be made. When tackling the large loss on Apostle I, there was sufficient evidence to reconstruct the folds of the missing sections of the sleeve and of the green cloak, but any folds that may have once been present in the drapery across the figure's chest could not be re-created. Instead, the internal modelling has been suggested, but not defined, by applying the retouching glazes with a stippled technique. Although the effect produced is similar to that of the cracked and broken glazes in the original paint, on close inspection the difference is quite apparent. The same method has been used for the larger losses on S. Thomas and S. Peter. In retouching the band of damage which runs along the hem of the former, the modelling of the green robe has been fully reconstructed but the embroidered pattern has not been replaced. Its absence was not felt to detract seriously from the sculptural solidity of the figure. Other relatively large retouchings, like those on Christ's torso and the feet of Apostle D can be identified by their texture and lack of craquelure.

The knowledge of Cima's technique gained by study of the sample cross-sections proved invaluable when matching the colours of the retouchings to those of the original paint. It was possible to imitate closely the layer structure of each colour area to reproduce the correct optical effects. The missing areas of each damaged drapery could first be blocked-in with an opaque undermodelling and then completed with layers of glaze, exactly according to Cima's system. At one point the possibility was briefly considered of leaving the large losses unglazed to indicate the extent of the damage, but the colours of the underlayers are much lighter than those of the completed paint structure, so the losses tend to float in front of forms, disrupting the image in a similar way to some of the visible methods of restoration referred to earlier.

The identification of most of the pigments used by Cima was also of considerable assistance in restoring the altarpiece; it enabled the most appropriate modern pigments for the retouchings to be chosen. This was particularly important in the areas of blue and green paint where the selection of the correct retouching pigment can help to avoid the problems of metamerism which frequently occur with these colours [52]: for example, by comparing the spectral reflectance curve for azurite, identified as the pigment used for the green-blue ceiling, with the reflectance curves for modern blue pigments, it was possible to see that of these, manganese blue (barium manganate) would be the most suitable equivalent on which to base an accurate colour match for this area of paint. Similarly, artificial ultramarine was shown to be the best alternative with which to retouch the areas of natural ultramarine, but only if it was applied over an underpaint of manganese blue since Cima's azurite underpaint is now partially visible. The copper-based green pigments, malachite and verdigris, also absorb light at the infra-red end of the spectrum, so they were matched with a mixed green based on manganese blue and opaque and transparent yellow pigments. Other modern pigments used include the red, orange and yellow cadmium colours, synthetic red and brown lakes, lamp black and titanium white. In keeping with the original, earth pigments were seldom used. The medium of the retouchings is mainly Paraloid B72, although some opaque watercolour was used to mask the old, blackened retouchings on the grey wall above Christ. The varnish used is Ketone N.

The altarpiece has been placed in a frame which is essentially the same frame designed when it was acquired in 1870, but with most of the excessive and inappropriate ornament removed (Figs. 20 and 21). While the need for the transfer and such extensive restoration is to be regretted, nevertheless it has made it possible for more to be discovered about the painting as a physical object than any other so far examined at the National Gallery. More importantly, the lengthy treatment has restored *The Incredulity of S. Thomas* to a condition of structural soundness and visual coherence so that it can once more be exhibited as the Collection's only major Venetian altarpiece of the period and the grandest and most ambitious of its considerable and varied holding of paintings by Cima.

Notes and references

1. Although poplar is the wood Cima is most likely to have used for his panels, only a few definite identifications of the wood species have been published. These include 'The Virgin and Child with S. John the Baptist' in the Louvre; see MARETTE, J., *Connaissance des Primitifs par L'Étude du Bois* (Paris 1961), p.258. Of the panels by Cima in the National Gallery only 'The Virgin and Child with a Goldfinch' (No. 634) has been firmly identified as being on poplar. 'Christ among the Doctors' in the Narodny Museum, Warsaw has, rather unexpectedly, been listed as being on lime; see BIAŁOSTOCKI, J. and SKUBISZEWSKA, M., *Muzeum Narodowe w Warszawie Galeria Malarstwa Obcego: Malarstwo Francuskie, Niderlandzkie, Włoskie do 1600* (Warsaw 1979), p.59. However, examples of Italian paintings on lime are

occasionally found; see MARETTE, J., *op. cit.*, pp.293–4.

2. The back of the panel before treatment is illustrated in WYLD, M. and DUNKERTON, J., 'The Transfer of Cima's "The Incredulity of S. Thomas"', *National Gallery Technical Bulletin*, 9 (1985), p.48, Fig.8.

3. WYLD, M. and DUNKERTON, J., *op. cit.*, p.38.

4. These are illustrated in WYLD, M. and DUNKERTON, J., *op. cit.*, p.50, Fig.9 and p.52, Fig.11. Cima himself was probably not responsible for the manufacture of the panel.

5. GETTENS, R. J. and MROSE, M. E., 'Calcium Sulphate Minerals in the Grounds of Italian Paintings', *Studies in Conservation*, 1, 4 (1954), pp.182–3. X-ray diffraction powder analysis carried out at the National Gallery of gesso grounds from Italian panels has confirmed these results. These include a sample from Cima's 'Virgin and Child with S. Andrew and S. Peter' in the National Gallery of Scotland, where the white inert was identified as being unburnt gypsum.

6. Although there are several instances of separate payments for the panel in surviving accounts for fifteenth- and sixteenth-century altarpieces, payments for the application of the gesso ground are less common. An interesting exception is the accounts for an altarpiece painted mostly by Fra Marco Pensabene between 1520 and 1521 and still on the high altar of the church of S. Niccolò in Treviso, in which a payment is made to 'Mistro Zan indorador per parte per aver inzesà la Pala dell' altar grande' [Master Zan the gilder for his part in having gessoed the altarpiece for the high altar]. These accounts also list a payment to 'Mistro Lio che faceva la Pala per comprar Formajo per far la cola da incolar le Tavole de dita Pala' [Master Lio who is making the altarpiece for buying cheese to make the glue for glueing the panels of the said altarpiece]. These documents were transcribed and published in FEDERICI, D. M., *Memorie Trevigiane sulle Opere di Disegno dal mille e cento al mille ottocento per servire alla Storia delle Belle Arti d'Italia* (Venice 1803), Vol.I, pp.130–31.

7. THOMPSON, D. V., *The Craftsman's Handbook: 'Il Libro dell' Arte' of Cennino d'Andrea Cennini*, Dover edition (New York 1954), pp.69–70. If there had been any indication of the use of an unusual material to size the panel, identification of it would have been difficult because the back of the gesso is heavily stained with adhesives used in attempts to treat the blisters and flaking.

8. Staining of a cross-section for protein with amido black 10B showed a banded variation in the concentration of animal glue within the ground, suggesting the gesso to have been applied to the panel in more than one layer. Clearly the flaking cannot be attributed to the addition of iron oxide to the gypsum or to the use of alternating layers of glue and gesso as is the case with two troublesome panel paintings by Giovanni Bellini and his workshop, 'The Madonna of the Meadow' (No.599) and 'The Assassination of S. Peter Martyr' (No.812). See HENDY, P., LUCAS, A. S. and PLESTERS, J. 'The Ground in Pictures', *Museum*, 11, 4 (1968), p.260.

9. LAZZARINI, L., 'Lo Studio Stratigrafico della Pala di Castelfranco e di Altre Opere Contemporanee' in *Giorgione: La Pala di Castelfranco Veneto*, Electra Editrice (Milan 1978), p.55.

10. Notable examples in the National Gallery include: 'The Madonna of the Meadow' (No.599) by Bellini, and 'The Circumcision' (No.1455) catalogued as Studio of Bellini.

LAZZARINI, L., *op. cit.*, pp.53, 55–6, illustrates samples with this layer from paintings by Carpaccio and Sebastiano del Piombo as well as the Cima referred to earlier. In a second article he lists this layer as being present in another painting by Cima, 'The Madonna dell'Arancio' in the Accademia, Venice, as well as in works by Carpaccio, Giovanni Bellini, Palma Vecchio, Sebastiano del Piombo, Lotto, Basaiti, Titian and Pordenone. See LAZZARINI, L., 'Il Colore nei Pittori Veneziani tra il 1480 e il 1580', *Bollettino D'Arte*, Supplemento 5 (1983), pp.138–41. This sealing of the ground with a size layer (or in some cases an oleaginous layer) is also recorded and discussed in VAN OS, H. W., VAN ASPEREN DE BOER, J. R. J., DE JONG-JANSEN, C. E., and WIETHOFF, C. (eds.), *The Early Venetian Paintings in Holland* (Maarssen 1978), pp.17, 31, 48 and 94.

11. See DUNKERTON, J., *Cima: With Special Reference to his Technique*, unpublished MA Report, Courtauld Institute of Art (1976), pp.6–7; and HUMFREY, P., *Cima da Conegliano*, Cambridge University Press (Cambridge 1983), p.63.

12. The incision of the most important lines of the architectural features can be seen in many works by Cima. In the X-radiographs of 'A Male Saint' (No.4945) and 'S. Sebastian' (No.4946) small white marks appear in the centres of some of the arcs incised for the semi-circles of the fluted, shell-shaped niches. These have probably been made by the fixed point of the dividers used to inscribe the circles. Like the incised lines, they show as white because the holes have been filled with X-ray opaque paint. In 'S. Sebastian' Cima seems to have had problems with the rather complicated perspective caused by the off-centre vanishing point, so some of the arcs have been re-drawn and the painted outlines do not necessarily coincide with the incised ones.

13. No preliminary drawings or studies for 'The Incredulity of S. Thomas' have survived and it is not certain how Cima transferred or enlarged his designs from paper to the gessoed panel. Although the study of the 'Head of S. Jerome' in the British Museum, is on the same scale as its painted counterpart for 'The Madonna dell'Arancio' in the Accademia, Venice, and the paper has been cut out around the outline and remounted, which might suggest that the paper has been damaged by pricking for transfer by pouncing, none of the details within the outline have been pricked and, so far, no pounced dots have been discovered by infra-red examination on paintings by Cima. A drawing of Orpheus in the Gabinetto dei Disegni of the Uffizi, Florence, which is sometimes attributed to Cima has been pricked for pouncing, but as always with pricked drawings, it is impossible to establish whether this was done by the artist or by a later owner of the drawing. With the exception of some 'mass-produced', workshop versions of the Madonna and Child associated with followers of Giovanni Bellini and of Cima (see VAN OS, H. W., *et al.*, *op. cit.*, pp.17–20, 45–7 and 125–6), the use of pouncing appears to have been less common among Venetian painters of the second half of the fifteenth century than among their Florentine and Umbrian contemporaries. However, the existence of a squared-up drawing of the Virgin and Child in the Boymans-Van Beuningen Museum, Rotterdam, attributed to Cima or a close associate, indicates that this method of transferring a design was in use in Cima's workshop. If it was used for 'The Incredulity of

S. Thomas' the lines of the grid would almost certainly have been drawn in charcoal or black chalk and dusted off once the underdrawing was completed.

14. A cross-section from 'A Male Saint' (No.4945) includes a layer of underdrawing. It has also been noted in cross-sections from 'Tobias and the Angel'. See LAZZARINI, L. (1978), *op. cit.*, p.55; and LAZZARINI, L. (1983), *op. cit.*, p.138.

15. Infra-red photographs of 'The Virgin and Child with a Goldfinch' (No.634), 'A Male Saint' (No.4945) and 'S. Sebastian' (No.4946) also show very little underdrawing, only the occasional outline being visible. On the other hand, examination by infra-red photography and reflectography of 'Christ Crowned with Thorns' (No.1310) revealed a detailed and highly finished underdrawing with the drapery and face modelled using a fine, hatched technique very like that seen in some of Giovanni Bellini's underdrawings and in his unfinished(?) 'Pietà' in the Uffizi. When 'Christ Crowned with Thorns' was cleaned, it became apparent that the underdrawing was almost certainly intended to show through the very thin, translucent paint layers and to contribute to the modelling of Christ's features. It would appear that, while Cima generally used his characteristic solid style of underdrawing, the extent and the amount of detail in the underdrawing varies considerably, perhaps depending on the scale of the work and on the existence or otherwise of preparatory studies on paper.

16. 'The Virgin and Child with S. Andrew and S. Peter' was examined for the National Gallery of Scotland by Joyce Plesters and Ashok Roy. Spectrographic analysis with the laser microprobe identified iron in samples of the underdrawing. In the infra-red reflectograms of the painting made by Simon Folkes, then of the Hamilton Kerr Institute, Cambridge, as part of a project on unfinished paintings, the drawing which has been protected by the paint layers produced a darker and clearer image than the areas of exposed and therefore faded drawing. When iron gall inks fade the black ferric gallotannate breaks down and alters to form a brown ferric oxide which absorbs little infra-red light, producing only a faint image in the infra-red reflectogram. To confirm that faded and unfaded iron gall inks produce faint and relatively dark images respectively in infra-red light, known samples of iron gall inks which had been exposed for a few years to natural daylight but with half of each sample covered, were examined with an infra-red vidicon.

17. These particles were taken to be carbon black as they were insoluble in concentrated hydrochloric acid.

18. THOMPSON, D. V., *op. cit.*, p.75.

19. MILLS, J. S. and WHITE, R., 'Analyses of Paint Media', *National Gallery Technical Bulletin*, 7 (1983), p.65. Linseed oil has also been identified by gas-chromatography as the medium of seven samples from 'A Male Saint' (No.4945) and 'S. Sebastian' (No.4946). See MILLS, J. S. and WHITE, R., 'Analyses of Paint Media', *National Gallery Technical Bulletin*, 1 (1977), p.58. The medium of 'The Virgin and Child with S. Michael and S. Andrew', in the Galleria Nazionale, Parma, has been identified by staining tests as oil; see FORNARI SCHIANCHI, L., NONFARMALE, O. and ROSSI-MANARESI, R., 'Esame Stratigrafico sul Dipinto con la Madonna col Bambino e i SS. Michele e Andrea', *Restauri a Cura della Soprintendenza ai Beni Artistici e Storici*

- di Parma e Piacenza*, Parma (1979), p.104. 'Tobias and the Angel' in the Accademia, Venice, is described as having been painted using a drying oil, but the method of medium identification is not recorded; see LAZZARINI, L. (1978), *op. cit.*, p.50.
20. Analysis by GC-MS. Dehydroabietic acid was detected in two samples of green glaze suggesting the use of a conifer resin.
21. MILLS, J. S. and WHITE, R., 'Analyses of Paint Media', *National Gallery Technical Bulletin*, 3 (1979), pp.66-7. Samples from the red-brown parapet and the blue paint of the mountains appeared to be essentially egg tempera, but with a small amount of oil, possibly as contamination from later restoration. The green leaves, on the other hand, contained mostly oil, perhaps with a little egg. The use of oil, sometimes mixed with resin, for areas of green in paintings which are otherwise in egg tempera, has been noted elsewhere on works by Cima (see VAN OS, H. W., *et al.*, *op. cit.*, p.57-8) and by other painters working in Italy in the late fifteenth- and early sixteenth-centuries, including Giovanni Bellini; see PACKARD, E. C. G., 'A Bellini Painting from the Procuratia di Ultra, Venice: An Exploration of its History and Technique', *The Journal of the Walters Art Gallery*, XXXIII-XXXIV (1970-1971), p.82. Other paintings by Cima recorded as being in egg tempera include 'The Crucifixion' in the Barber Institute, Birmingham (based on solubility tests made at the Hamilton Kerr Institute, Cambridge) and 'Christ among the Doctors' in Warsaw; see BIALOSTOCKI, J. and SKUBISZEWSKA, M., *op. cit.*, p.59 (the method of identification is not specified).
22. The use of azurite as an underpaint for ultramarine occurs on many fifteenth-century paintings, among them several by Cima. Examples include 'The Virgin and Child' (No.300), and 'Christ Crowned with Thorns' (No.1310) in the National Gallery, and 'The Virgin and Child with S. Michael and S. Andrew' in Parma; see FORNARI SCHIANCHI, L., *et al.*, *op. cit.*, p.10. (In connection with this painting, I am very grateful to Raffaella Rossi-Manaresi for sending photographs of the cross-sections, as they are not illustrated in the article.) The Virgin's robe in the unfinished 'Virgin and Child with Saints and Donors' in Cleveland, apparently has the green-blue colour characteristic of azurite. It was probably intended to be completed with an ultramarine glaze; see HUMFREY, P., *op. cit.*, pp.62-3. Ultramarine has also been found without the azurite underpaint on some of Cima's smaller scale works: these include 'The Virgin and Child with a Goldfinch' (No.634), 'A Male Saint' (No.4945) and the 'Virgin and Child' in the Rijksmuseum; see VAN OS, H. W., *et al.*, *op. cit.*, p.57.
23. In the cross-section made from a sample taken from an area of shadow on S. Peter's chest a thin layer of old restoration containing Prussian blue could be seen. It may be that the remains of later retouchings are the cause of the discoloration on some of the darker areas of this drapery.
24. These include 'The Virgin and Child with a Goldfinch' (No.634) in the National Gallery. It also occurs in the Rijksmuseum 'Virgin and Child' (see VAN OS, H. W., *et al.*, *op. cit.*, pp.57-8), the 'Madonna dell'Arancio' (see LAZZARINI, L. (1983), *op. cit.*, plate XII, no.3) and 'The Virgin and Child with S. Michael and S. Andrew' (see FORNARI SCHIANCHI, L., *et al.*, *op. cit.*, p.11).
25. Among them are Carpaccio (see LAZZARINI, L. (1983), *op. cit.*, p.55), Sebastiano del Piombo, and Giorgione (see LAZZARINI, L. (1978), *op. cit.*, pp.51-5).
26. Samples from 'S. Sebastian' (No.4946) show that his pink loincloth has been painted with an identical pigment mixture.
27. The three separate layers of glaze only became visible when the cross-section was examined under the microscope in ultra-violet light. This also confirmed that a blackish line at the top of the section was the remains of old repaint.
28. Red lake glazes from the draperies of Apostle A and S. Thomas. Identification by Raymond White using HPLC.
29. Spectrographic analysis of two samples of red lake from the draperies of Apostles A and I showed aluminium to be the principal element in the substrate.
30. Unfortunately, because of the fragile condition of the altarpiece before treatment, only one X-radiograph could be taken (of Christ's head). Once the painting had been transferred, X-radiography was made impossible by the interference to the image from the aluminium honeycomb core of the new support. Therefore any pentiments and re-working of areas can only be identified by examination of the surface and the layer structure of the painting.
31. These include 'The Entombment' (No.3084) by Andrea Busati (a close follower of Cima), a 'Virgin and Child' in the Dienst Verspreide Rijkscollecties, The Hague, attributed to the School of Giovanni Bellini (see VAN OS, H. W., *et al.*, *op. cit.*, p.48) and, in particular, paintings by Tintoretto, for example, 'The Origin of the Milky Way' (No.1313); see PLESTERS, J., 'Tintoretto's Paintings in the National Gallery', *National Gallery Technical Bulletin*, 4 (1980), p.39 and Plate 5, p.47.
32. Although particles of haematite are quite commonly found in paint mixtures containing earth pigments, it is rarely noted as a pure pigment in its own right. XRD of a carefully separated sample of dark red underpaint gave clear patterns for haematite (JCPDS file No.24-72), lead white (JCPDS file No.13-131) and neutral lead carbonate (JCPDS file No.5-417). See also Note 43 below.
- A mixture of haematite and vermilion in a drying oil has been identified as the contents of a small, glazed ceramic pot, dateable to the second half of the sixteenth century, in the Galleria Franchetti in the Ca' d'Oro, Venice. These pots were probably used by painters to store prepared colours so that they were ready for use. See LAZZARINI, L. (1983), *op. cit.*, p.136 and plate XI.
33. The identification of a conifer resin, probably pine, in the medium of the green glazes (see p.10 of this article) means that these are true 'copper resinate' glazes with the verdigris dissolved in an oleo-resinous medium. A small proportion of lead white was found by XRD in a sample of green 'semi-glaze' from S. Thomas's mantle; no other crystalline phases are present. The opaque components incorporated into the 'copper resinate' layers are clearly seen in thin cross-sections from the greens.
34. Other examples of multi-layered greens on Venetian paintings include the drapery on Palma Vecchio's 'A Blond Woman' (No.3939), the School of Giovanni Bellini 'Virgin and Child' in The Hague, also noted for its complex reds (see VAN OS, H. W., *et al.*, *op. cit.*, pp.18 and 48)

and on works by Sebastiano del Piombo; see LAZZARINI, L. (1978), *op. cit.*, p.54.

35. Thin paint cross-sections were prepared in the manner commonly employed for geological specimens. Samples embedded in polyester resin blocks, ground and polished, were stuck to microscope slides with cyanoacrylate glue, the exposed cross-sectional surface in contact with the glass. The back of the resin block was then ground down and polished to a thin sliver of between $c.20\text{--}50\mu$ for transmitted light microscopy.

36. In all samples examined, XRD showed the lead-tin yellow used to be of the form designated 'type I' (JCPDS file No. 11–233), see KÜHN, H., 'Lead-tin Yellow', *Studies in Conservation*, **13**, 1 (1968), pp.7–33. Lead and tin were detectable in the samples by LMA.

37. These include Veronese's 'The Family of Darius before Alexander' (No.294) and his series of 'Allegories of Love' (Nos.1318, and 1324–26); 'Christ and the Woman taken in Adultery' in the Glasgow City Art Gallery, attributed to Giorgione and possibly Titian's 'The Death of Actaeon' (No.6420).

An orange pigment thought to be of an organic nature has been noted on Girolamo dai Libri's 'Ariadne on Naxos' in the Rijksmuseum; see VAN OS, H. W., *et al.*, *op. cit.*, p.99.

LAZZARINI, L. (1983), *op. cit.*, pp.137–41, records several instances of the use of a bituminous pigment for brown glazes on paintings by among others Carpaccio, Giovanni Bellini and in particular, Titian, but the method of identification is not mentioned. The contents of another glazed ceramic pot similar to that referred to in Note 32 are reported to have been identified as bitumen.

'Aspalto' is mentioned as a pigment in the late sixteenth-century 'Volpato Manuscript'; see MERRIFIELD, M. P., *Original Treatises on the Arts of Painting*, Dover Edition (New York 1967), Vol. II, p.747.

38. XRD of a sample of this translucent yellow mixture showed the main crystalline phase present to be calcite (chalk), whilst calcium, aluminium, lead, tin, iron and silicon were detectable by LMA. It is possible that chalk was used as a substrate for a yellow lake pigment, and that the other elemental components arise from admixture with lead-tin yellow and a little yellow earth pigment. Aluminium is commonly found in natural earths, although equally may derive from a lake on an alumina substrate. The exact nature of the pigment mixture cannot be established in this case.

39. A yellow dyestuff which has been identified by thin-layer chromatography as Persian berries or buckthorn occurs in a mixture of ultramarine and lead white in an area of green paint on a work attributed to Carlo Crivelli; see VAN OS, *et al.*, *op. cit.*, p.68.

That Cima may have used a mixture of yellow pigments rather than yellow ochre alone on other occasions is suggested by the dense appearance in an X-radiograph of 'The Virgin and Child with a Goldfinch' (No.634) of a similar embroidered pattern on the Virgin's sleeve.

40. This is the earliest identification of the combination of orpiment and realgar on a painting in the National Gallery. However, both pigments have also been found on 'The Madonna dell'Arancio' which was probably painted in the mid-1490s; see LAZZARINI, L. (1983), *op. cit.*, p.139. Cima seems to have been one of the first painters to make use of these two pigments which were to become such a marked

feature of many Venetian paintings of the sixteenth century.

41. Orpiment and realgar in S. Peter's robe were detected initially by microscopy and confirmed in several samples spectrographically (LMA). The presence of realgar in a mid-tone was shown by XRD (JCPDS file No.24–77). Shadow areas on the robe were found to contain iron, manganese and a little lead in addition to arsenic (LMA).

42. In a sample of the darkest grey of the wall, the concentration of bone black was sufficiently high for the calcium phosphate content of the pigment to be detected by XRD (JCPDS file No. 18–303).

43. XRD of a sample of white from Christ's grey drapery confirmed the use of lead white (basic lead carbonate) containing a moderate proportion of neutral lead carbonate.

44. A similar mixture (but with vermilion instead of haematite) occurs in the dark brown hair of the figure of S. Mark in Giovanni Bellini's 'Barbarigo Altarpiece'. See LAZZARINI, L., 'Le Analisi di Laboratorio', *La Pala Barbarigo di Giovanni Bellini*, Quaderni della Soprintendenza ai Beni Artistici e Storici di Venezia, **3** (1983), p.26.

45. A major pentiment, by Cima's standards, has recently been revealed by computerized image processing of infrared reflectograms in 'The Virgin and Child with Saints' (the 'Pala Dragan') in the Accademia, Venice. The head of S. Catherine which is now turned towards the viewer was originally painted in profile. See BONARRIGO, A., SPEZZANI, P. and VALCANOVER, F. (eds.), *Riflettoscopia all'Infrarosso Computerizzata*, Quaderni della Soprintendenza ai Beni Artistici e Storici di Venezia, **6** (1984), pp.42–7.

46. For a discussion of Cima's workshop and its practices, see HUMFREY, P., *op. cit.*, pp.61–9.

47. Cennini gives detailed instructions on the manufacture of both miniver and hog's bristle brushes. See THOMPSON, D. V., *op. cit.*, pp.40–1.

48. For an account of the Venice pigment trade, see LAZZARINI, L. (1983), *op. cit.*, pp.135–6.

49. See GAVEL, J., *Colour: A Study of its Position in the Art Theory of the Quattro- and Cinquecento*, Stockholm Studies in the History of Art, **32** (1979), pp.91–2 and 95.

50. In 'The Incredulity of S. Thomas' the influence of contemporary Venetian sculpture on Cima appears to be particularly strong. Some of the figure types, for example Apostle D (S. John?), are reminiscent of those of the Lombardi, and the composition of Cima's altarpiece seems to be related to that of a relief by Tullio Lombardo of 'The Coronation of the Virgin' in S. Giovanni Crisostomo, Venice. This is usually dated *c.* 1502. The date when Cima actually began his altarpiece (as opposed to its commissioning) is not certain but given the rather frieze-like arrangement of the figures, it is more probable that his design was dependent on the sculpted relief rather than the other way round. See also HUMFREY, P., *op. cit.*, p.110.

51. For the theory and practice of 'abstract chromaticism' see BALDINI, U. and CASAZZA, O., *The Cimabue Crucifix*, Royal Academy of Arts, London (1983), pp.42–57; and BALDINI, U., *Teoria del Restauro e Unità di Metodologia*, Florence, Vol.I (1978), and Vol.II (1981).

52. See STANFORTH, S., 'Retouching and Colour Matching: The Restorer and Metamerism', *Studies in Conservation*, **30**, 3 (1985), pp.101–111.